SPACECRAFT INDUCED MOLECULAR RETURN FLUX CONSIDERATIONS FOR ICY MOON MISSIONS TARGETING DETECTION OF ORGANICS WITH MASS SPECTROMETERS

C.E. Soares[1], **W.A. Hoey**[1], J.R. Anderson[1], N.W. Ferraro[1], and D.A. Fugett[1]

Jet Propulsion Laboratory[1], California Institute of Technology, Pasadena, CA 91109

Contact e-mail: Carlos.E.Soares@jpl.nasa.gov.

Introduction

Science missions targeting the detection of organics from jet plumes originating from icy moons (i.e. Europa and Enceladus) will employ next-generation, state-of-the-art mass spectrometers to measure the composition of icy moon plume effluents and exospheres.

During fly-bys, as mass spectrometers make their scientific measurements, molecular emissions from the spacecraft can interact with the local exosphere and associated jet plumes from the sub-surface oceans of the icy moons. Spacecraft-induced molecular effluents collide with molecules from the ambient exosphere, and a fraction of the spacecraft emissions are returned to the spacecraft and its complement of science instruments. The rate at which emitted molecules are returned to the spacecraft by collisions with other molecules (e.g. in Europa's exosphere) is the *return flux*.[1]

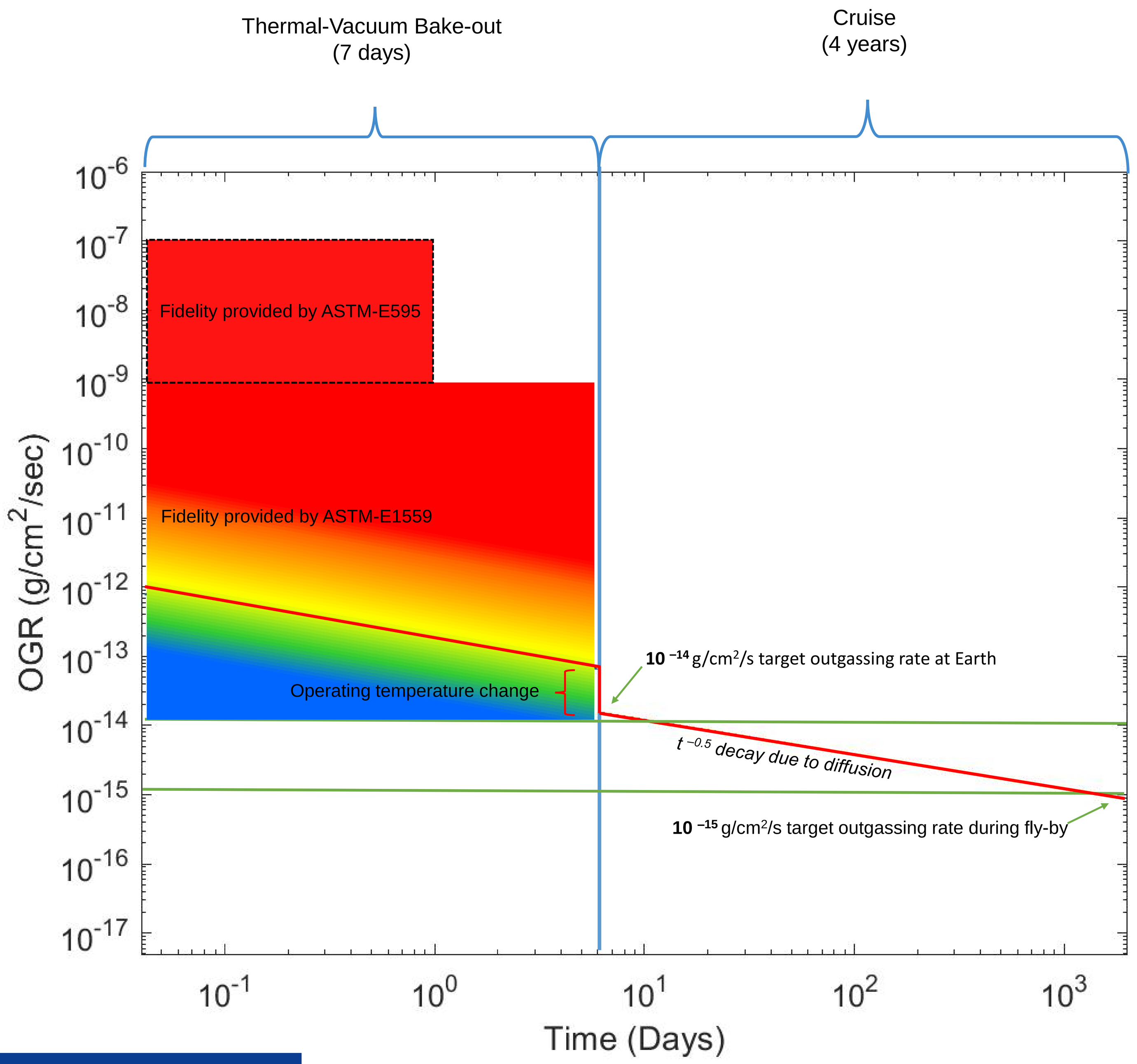
The **return flux of molecular emission from spacecraft sources is a major contributor to contaminant deposition onto the complement of contamination-sensitive instruments.** Characterization of return flux is critical to the definition of requirements for materials outgassing for the spacecraft and its instruments, and for the definition of thruster operations.

Contaminant Sources

Sources of self-induced contamination include the outgassing or desorption of molecular contaminants from a spacecraft's external surfaces, venting of internal emissions through seams in thermal blanketing, and the dispersion of gas- and liquid-phase propellant byproducts during thruster operations. **During fly-bys, materials outgassing is expected to be the dominant contributor to return flux.**

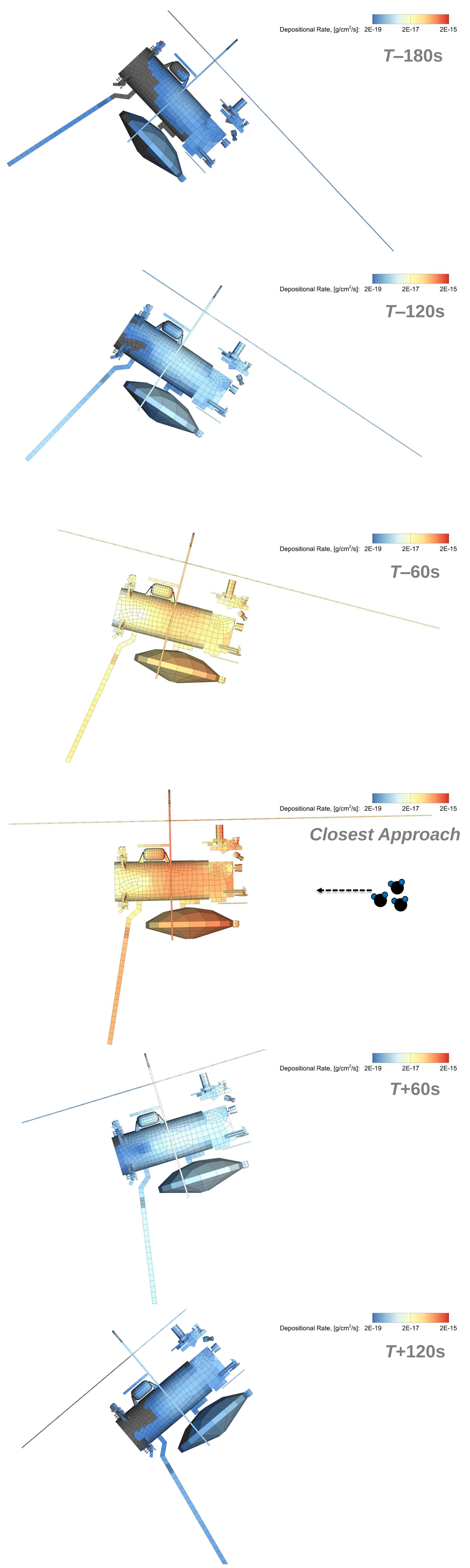
To support science missions with high sensitivity to molecular return flux, low outgassing rates are required: typically **1.0E–14 to 1.0E–15 g/cm²/s during fly-bys**. Screening materials with the typical ASTM-E595 standard [6] is inadequate in these regimes, as the total mass loss (TML) and collected volatile condensable materials (CVCM) criteria translate to relatively high outgassing rates: 1.0E–7 to 1.0E–9 g/cm²/s. Adequate characterization of condensable outgassing is only possible using the ASTM-E1559 standard,[7] with mass spectrometry of outgassing effluents.

Figure 1: Desired materials outgassing rates, and how to attain them.



Methodology

Two methodologies were evaluated for modeling return flux: the Boltzmann-BGK method [2] and the direct simulation Monte-Carlo method (DSMC).[3,4] An implementation of the BGK method developed by Roussel, Soares and Schmidl [5] was employed in this work for its relative computational efficiency in computing ambient scatter and return flux to a typical spacecraft geometric model of 10,000–100,000 surface elements.



Results

Figure 2 (at right): Spacecraft colored by rate of return flux originating from the solar array back-side during a close-approach fly-by (sequential instances are shown, spaced by minute). In this reference frame, the atmosphere is incident from right to left. **Note the tendency of ram-directed outgassing to return to spacecraft surfaces.**

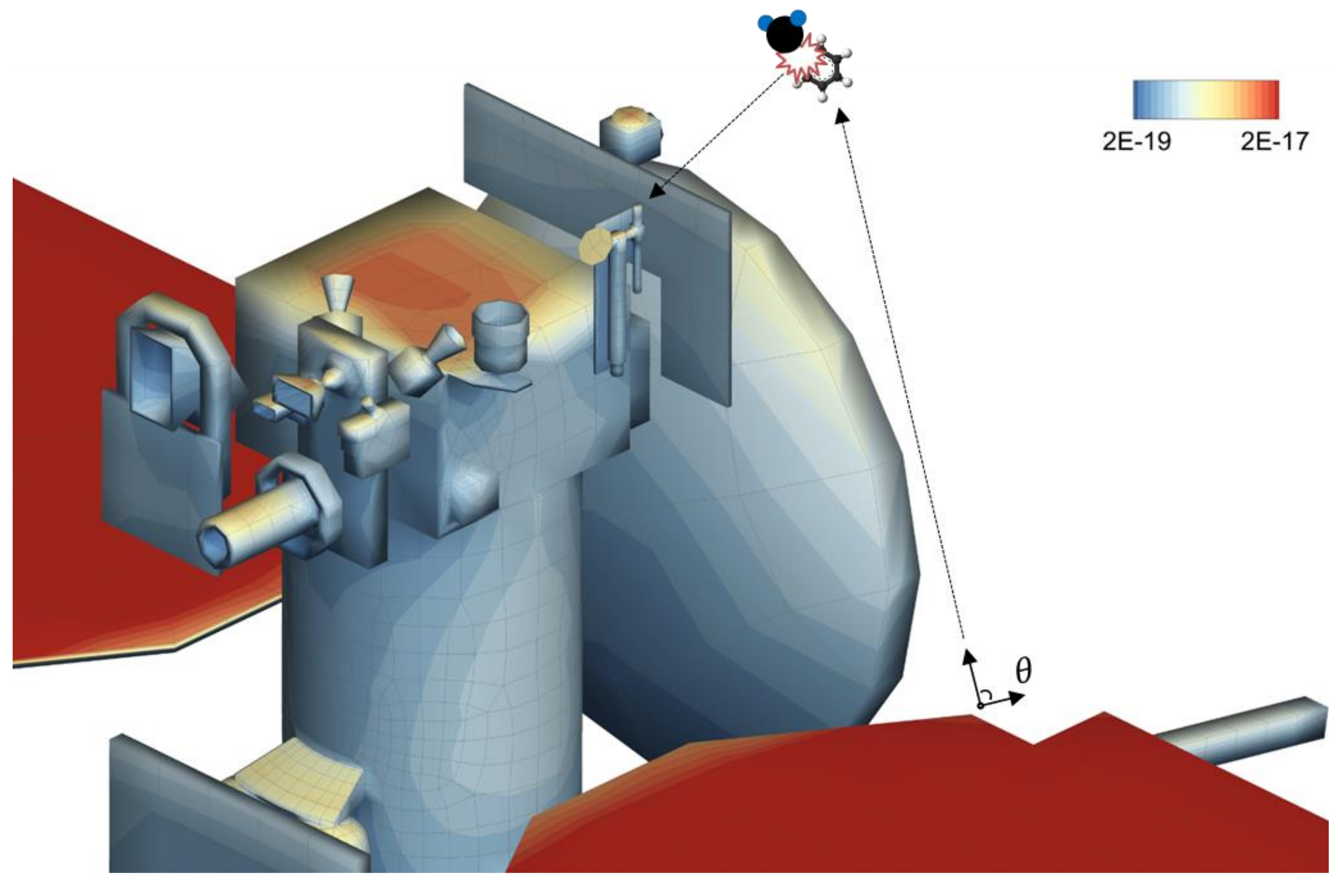


Figure 3 (above): Return flux originating from spacecraft ram-facing solar array panels in a typical Europan fly-by. An overlaid illustration depicts a solar-array-outgassed benzene molecule colliding with exospheric water and returning to enter an instrument. [Nominal rates shown in g/cm²/s].

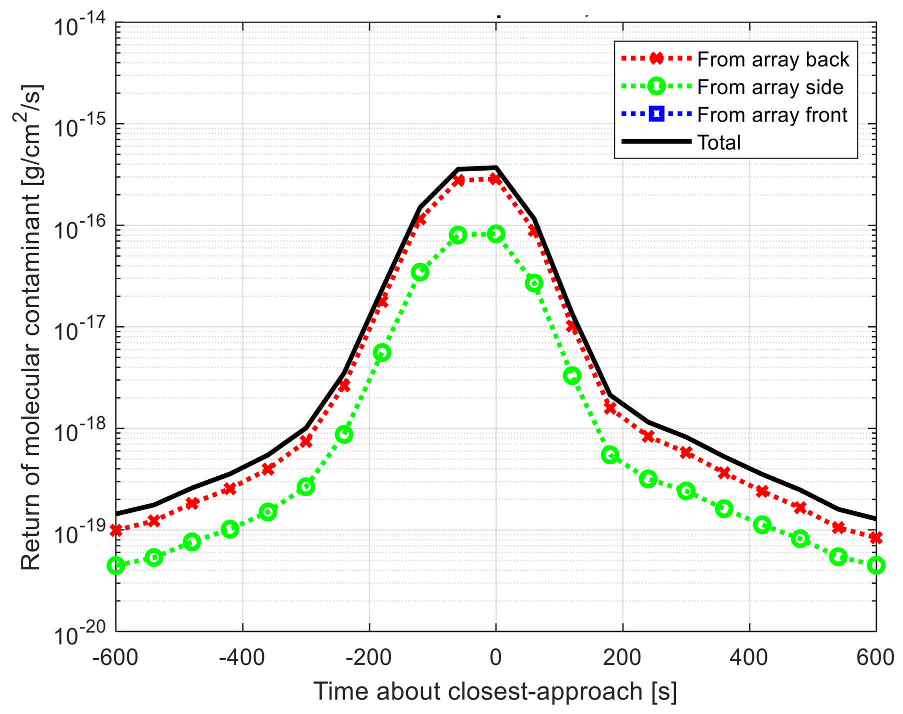


Figure 4*:* Return flux contributions to an instrument from a typical Europan fly-by. The solar array's ram-facing backside dominates the return flux contribution to the instrument suite. Active-side (solar cell) contributions are negligible.

Table 1 (below): Representative outgassing rates from a solar array on a typical flight system, and the respective molecular return flux from a Europan fly-by.

Table 1: Contaminant Source	Representative Outgassing Rates (g/cm²/s)	Molecular Return Flux to instruments (g/cm²/s)	Molecular Return Flux to instruments (g/cm²/s)
Solar array active side (solar cell side)	1.0E–14	--	5.0E–16
Solar array thermal side (backside)	3.0E–14	4.0E–16	
Solar array edges (composite panel venting)	2.0E–12	9.0E–17	

Conclusions

Spacecraft self-induced molecular return flux contributions to science instruments are significant – in particular to next-generation and state-of-the-art mass spectrometers intended to detect organics – and must be characterized to ensure that mission science objectives can be achieved.

The cases illustrated here, generated for a typical Europan fly-by, show a return flux of approximately 1% of the effective outgassing rate from a solar powered spacecraft configuration. Hence, **selection of low-outgassing materials (e.g., exhibiting rates of 1.0E–14 to 1.0E–15 g/cm²/s) is desired to limit molecular return flux from the flight system to science instruments.**

References

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Jet Propulsion Laboratory
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